

Biopsychosocial perspective on a mechanisms-based approach to assessment and treatment of pain following spinal cord injury

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Abstract—This article applies a biopsychosocial perspective to a mechanisms-based approach to the assessment and treatment of the heterogeneous and persistent pain conditions associated with spinal cord injury (SCI). This article presents an overview of the types of pains experienced after SCI and some of the research on the mechanisms, diagnostic issues, and psychosocial factors relevant for the development of treatments targeting specific underlying mechanisms of pain. This review also discusses several diagnostic challenges of determining the underlying causes of pain in each individual patient.

Key words: affective distress, coping, evoked pain, neuropathic pain, pain assessment, pain classification, pain mechanisms, rehabilitation, sensory examination, spinal cord injury, treatment.

INTRODUCTION

Pain following spinal cord injury (SCI) is an extremely difficult problem to manage because of its many contributing pathophysiological and psychosocial factors. In recent years, interest has been increasing in the development of a mechanisms-based approach to the treatment of pain in the hope that such an approach will produce better outcomes. Some efforts have been made to apply this

mechanisms-based approach to the assessment and treatment of pain following SCI. However, a number of unresolved issues remain regarding the adoption of this approach and the development of an integrated approach that accounts for both pathophysiological and psychosocial factors contributing to the pain. This article aims to (1) provide a biopsychosocial perspective on the assessment and treatment of SCI-related pain [1] and (2) discuss some of the challenges of designing future mechanisms-based treatment strategies that account for these different contributing factors.

Abbreviations: GABA = γ -aminobutyric acid, IASP = International Association for the Study of Pain, MPI = Multidimensional Pain Inventory, MPI-SCI = MPI (Spinal Cord Injury version), NIDDR = National Institute on Disability and Rehabilitation Research, NMDA = N-methyl-D-aspartate, QST = quantitative sensory testing, SCI = spinal cord injury.

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DEFINING ISSUES

Complexity of Pain Following SCI

After SCI, a person commonly experiences several types of pain, some of which do not respond well to treatment [2–3]. Because SCI is associated with multiple physical impairments, the additional burden of persistent pain decreases the person's chances for an optimal quality of life [4–5]. Pain following SCI depends on multiple pathophysiological mechanisms, as well as on individual psychosocial characteristics; therefore, the ideal treatment should be tailored to these specific mechanisms.

Mechanisms-Based Treatment

A large body of basic research suggests that a multitude of pathophysiological mechanisms, either alone or in combination, may cause specific sensory signs and symptoms such as burning pain, heat hyperalgesia, or mechanical allodynia [6]. These signs and symptoms are important because they suggest that neuropathic pain associated with different clinical conditions (e.g., SCI, traumatic brain injury, multiple sclerosis) may share similar underlying pathophysiology. Thus, a mechanisms-based treatment strategy is based on the concept that treatment can be tailored to clinical signs and symptoms that indicate the specific mechanisms important for both the generation and the maintenance of pain [7–9]. However, several issues make a complete mechanisms-based evaluation difficult and these will be discussed in more detail in the next section.

Comprehensive Pain Evaluation

A mechanisms-based treatment of persistent pain after SCI requires a comprehensive pain evaluation that captures information regarding the specific symptoms of pain, relevant psychosocial factors, sensory dysfunction, and general medical status, including the determination of neurological level of injury. Quantitative sensory testing (QST) is designed to examine the functional integrity of somatosensory pathways. For example, thresholds to mechanical and vibratory stimulation can be used for the assessment of large fiber and dorsal column function, and thermal detection or pain thresholds can be evaluated for the assessment of small-fiber or spinothalamic tract function [10]. Several studies indicate that QST may be useful for evaluating sensory dysfunction associated with specific pain phenotypes [11–12]. Although preliminary evidence supports the stability and validity of QST use for a deter-

mination of sensory dysfunction after SCI (see Felix and Widerström-Noga, p. 69 of this issue) more research is needed for a conclusive investigation of the ability of QST to determine specific pathophysiological mechanisms of SCI-related pain [13]. Similarly, few of the pain-related measures used in other pain populations have been adequately tested after SCI regarding their psychometric properties [13–14].

Coping with Pain

While some treatments reduce the severity of pain in some individuals [15–16], no treatments that are currently available consistently relieve pain in the SCI chronic pain population. Therefore, the majority of people with SCI will have to learn to cope with their pain. Persistent pain is one of the consequences of SCI that has repeatedly been shown to significantly decrease perceived quality of life [4–5] and to interfere with cognitive, emotional, and physical health and functioning, including sleep [5,17–18]. Indeed, pain relief has been identified as one of the highest areas of unmet need in a recent European study of 1,000 individuals with SCI [19].

According to the biopsychosocial model of pain, cognitive, emotional, social, and pathophysiological factors contribute to the experience of pain [1]. The biopsychosocial approach to the management of pain aims to increase individual coping skills to improve quality of life. Therefore, treatment strategies that include cognitive-behavioral components directed toward enhancing a person's coping ability and adaptation to pain are important components of multidisciplinary management of pain after SCI [20–22].

CLINICAL PRESENTATION OF SCI-RELATED PAIN

Musculoskeletal Pain

Several types of pain are commonly observed following SCI. If the injury is traumatic, acute pain may arise from damage to surrounding musculoskeletal structures including bones, ligaments, muscles, intervertebral discs, and facet joints. Nociceptors are activated in these regions and the pain is therefore generally located in the region of preserved sensation close to the site of the SCI, although it may radiate to other regions. Chronic musculoskeletal pain may also occur with overuse or abnormal use of structures such as the arm and shoulder and in association with muscle spasms [23–24].

Visceral Pain

Visceral pain may arise from pathology in visceral structures, such as urinary tract infection, bowel impaction, and renal calculi. Although the level of SCI influences the type of neurogenic bowel dysfunction, the level of injury does not seem to predict the presence of abdominal pain [25]. Activation of nociceptors by constipation may be an underlying mechanism of abdominal pain in some patients and appears to be more common in patients with long-term SCI [26].

Neuropathic Pain

Neuropathic pain following SCI is sometimes regarded as a single entity and referred to as central pain or SCI-related pain. However, two distinctly different types of neuropathic pain appear to be specifically related to SCI [26]. The first type is present in a segmental distribution anywhere within the dermatome of the level of neurological injury and three dermatomes below this level [27]. For this reason, this type of pain is often referred to as segmental, transitional zone, border zone, end zone, girdle zone, or at-level neuropathic pain. The second type of pain occurs diffusely below the neurological level of SCI and is present in the region more than three dermatomes below the neurological level of injury [27]. This type of pain may develop many months, and even years, following injury [28]. This pain is also referred to as central dysesthesia syndrome, central pain, SCI phantom pain, deafferentation pain, or below-level neuropathic pain. This type of pain is typically constant, varies with mood or attention, and is usually unrelated to position or movement. The pain may be triggered by sudden noises or physical jarring and exacerbated by other pathology, such as urinary tract infections or disturbance of bowel function.

Some authors suggest that neuropathic pain can be distinguished from musculoskeletal pain on the basis of descriptors such as “burning,” “electrical,” or “shooting.” However, descriptors alone are often poor indicators of pain type. Although words such as “tingling” and “burning” are more common in people with neuropathic pain and “aching” in musculoskeletal pain, a great deal of overlap exists [29]. Neuropathic pain either at or below the level of injury may be associated with allodynia (pain caused by a normally nonpainful stimulus) or hyperalgesia (an exaggerated pain response) in the affected dermatomes.

MECHANISMS UNDERLYING SCI PAIN

Musculoskeletal Pain

The underlying pathophysiological mechanisms of musculoskeletal pain in a person with SCI are similar to those found in the general population. However, this type of pain may be initiated by the physical impairment associated with the SCI. For example, musculoskeletal pain involving the neck, shoulders, and upper limbs may be related to overuse, extreme joint postures, high mechanical stresses, and repetitive movements associated with transfers and use of wheelchairs. Pain in the area of the vertebral column, on the other hand, may be secondary to dislocations, scoliosis, mechanical instability, or osteoporosis. Musculoskeletal pain may also be caused or aggravated by muscle spasms.

Neuropathic Pain

The two types of neuropathic pain described earlier are specific to SCI, and a fairly large body of research now characterizes the possible contributing mechanisms [30–31]. While below-level neuropathic pain is a consequence of the damage to the spinal cord, at-level neuropathic pain may arise from damage to spinal nerve roots or the spinal cord itself. With at-level neuropathic pain, distinguishing between peripheral (root pathology) and central (spinal cord pathology) mechanisms can often be difficult. However, unilateral pain exacerbated by spinal movement may indicate nerve root damage. Trauma to the spinal cord, by various causes, may result in compression, demyelination, inflammation, and ischemia [30]. This damage triggers secondary pathological changes in the spinal cord. For example, loss of inhibitory interneurons and lesions of descending inhibitory tracts, along with increased neuronal excitability, leads to abnormal firing of neurons close to the level of SCI, which then contributes to the generation of nociceptive signals and the experience of pain [31].

Brain mechanisms are also important in pain perception following SCI. Neuroimaging studies indicate that pain perception depends on a network of cortical and subcortical structures such as the thalamus [32]. These regions contribute to the various discriminative, associative, evaluative, and emotive tasks and responses that contribute to the experience of pain. For example, SCI-related pain has been shown to be associated with alterations in thalamic neuronal firing [33], expression of sodium channels [34], biochemical changes [35], and changes in thalamic perfusion or activity [36]. These changes, as well as possible changes in other brain regions, may contribute to the presence of pain.

TOWARD A MECHANISMS-BASED SCI PAIN TAXONOMY

Current Situation

Many classification systems have been published that attempt to either simply list or provide a systematic framework that brings together the different types of pain that people report following SCI [26,37–39]. Despite these many publications, a lack of consensus still exists on which classification system should be used. Moreover, the systems clearly need additional work to establish reliability, specifically test-retest reliability, and validity [13,29]. However, efforts continue on a collaborative basis to devise a taxonomy of SCI pain that meets the needs of people working in this area.

As mentioned earlier, a strong move has occurred in the pain field toward developing a mechanisms-based approach to classification and management of pain [6–7,40]. This move is reflected in the SCI pain taxonomy published by the International Association for the Study of Pain (IASP), which proposes a three-tiered structure, with the third tier designed to indicate the specific structures or pathology contributing to the pain [41]. The rationale for this approach is that it will help identify appropriate and effective treatments that specifically address the causative mechanisms underlying the specific type of pain.

Future Challenges

To base a treatment on causative mechanisms is intuitively appealing. However, several difficulties arise in the application of such treatment to SCI-related pain. One difficulty is that the mechanisms responsible for neuropathic SCI-related pain are not completely known. Although a growing body of research exists in this area, neuropathic pain may depend on a complex combination of peripheral, spinal, and supraspinal mechanisms that may contribute to varying degrees in each individual. Furthermore, multiple cellular mechanisms have been identified, including changes in N-methyl-D-aspartate (NMDA) and other glutamate receptors, sodium channels, microglia, and γ -aminobutyric acid (GABA)-ergic, opioidergic, serotonergic, and noradrenergic function [30,42–43].

Another difficulty is that no exact knowledge exists on how to conclusively link the symptoms and signs of pain observed in the patient to any particular mechanism. As will be described in the next section, more sophisticated techniques such as QST may help to precisely link the signs associated with neuropathic pain in a particular person to a potential mechanism. However, as yet, no

method exists to definitively link a particular symptom or sign, or constellation of these, to a specific mechanism. Until this definitive linking is possible, mechanisms-based treatments cannot be designed with any precision.

Finally, mechanisms-based approaches understandably focus on biological mechanisms [40]. However, because the biopsychosocial perspective of pain identifies psychological and social factors as major contributors to the pain experience, these factors need to be integrated in this approach. This means that a biological mechanisms-based approach, no matter how accurate, may fail to provide the best relief of pain unless it is integrated with a biopsychosocial perspective that then allows the practitioner to address the various biological, psychological, and social or environmental factors that, together, contribute to the person's experience of pain.

DIAGNOSTIC APPROACH TO SCI PAIN

Identifying Neuropathic Pain

As discussed in the previous section, an accurate mechanisms-based classification should facilitate the identification of different pain conditions with separate underlying mechanisms. The first important distinction is between neuropathic and nociceptive types of pain, because of the differences in prognosis and treatment approaches between these conditions [28,44]. However, specific diagnostic criteria that can consistently diagnose neuropathic pain are currently not available for those with SCI.

Neuropathic pain has been defined by the IASP as "pain initiated or caused by a primary lesion or dysfunction in the nervous system" [45]. However, Treede et al. recently suggested omitting "dysfunction" from this definition, defining neuropathic pain as "pain arising as a direct consequence of a lesion or disease affecting the somatosensory system" [46]. Within this revised definition, a grading system of "definite," "probable," and "possible" neuropathic pain was proposed. For the diagnosis of definite neuropathic pain, Treede et al. suggested that the following criteria be fulfilled: (1) a neuroanatomically plausible pain distribution, (2) a history of a relevant lesion or disease affecting the peripheral or central somatosensory system, (3) negative or positive sensory signs within the body area corresponding somatotopically to central nervous system injury or peripheral nerve or root, and (4) a diagnostic test confirming a lesion or disease involving central or peripheral nervous structures relevant for the presence of neuropathic pain.

In many cases, the diagnosis of neuropathic pain is simple based on these criteria. However, in some cases, the diagnosis is difficult, particularly if the pain is localized in smaller areas below the injury level in incomplete SCI and is increased by movement or spasms. In these cases, the presence of a sensory abnormality, even for temperature, does not support the diagnosis of neuropathic pain because such abnormalities are equally common in patients without neuropathic pain [47]. Thus, the exclusion of nociceptive pain by further imaging, e.g., X-ray, is necessary.

Statistical clustering of specific pain features, such as burning, tingling, pricking, shooting, freezing pain, the presence of evoked pain, and the lack of predominantly joint pain, has been shown to provide some guidance in the distinction between neuropathic and nonneuropathic pain [48]. Tools based on such clustering have a diagnostic sensitivity and specificity of about 80 percent [49]. However, these instruments have not been validated in SCI pain, where paraesthesia, e.g., tingling and cold sensations, are very common, even in the absence of neuropathic pain. Therefore, the diagnosis of neuropathic pain after SCI is not always simple, and further validation of the diagnostic criteria for neuropathic pain is needed.

Translation from Symptoms and Signs to Mechanisms

Even within the diagnosis of neuropathic pain, the constellation of different symptoms and signs varies among individuals. Therefore, the translation of clinical signs and symptoms into a further understanding of the underlying mechanisms is difficult. So far, few clinical trials have tried to group SCI patients according to symptoms and signs rather than disease etiology. Drugs such as gabapentin, pregabalin, and tricyclic antidepressants have a general mechanism of action and can relieve many types of pain, including peripheral and central neuropathic pain (spinal cord as well as brain lesions) [50] and other types of pain, such as fibromyalgia and postoperative pain. Therefore, these drugs will likely not have differential effects on at- versus below-level neuropathic pain or spontaneous versus evoked pain. This lack of drug specificity was also apparent in a randomized controlled trial in SCI neuropathic pain [15]. However, with the development of new drugs with more specific targets, such differentiation may gain importance in the future.

Examination of sensory function and dysfunction is important for both the diagnosis and evaluation of neuropathic pain. Bedside clinical examination of sensory func-

tion, and the more time-consuming QST, can assess both decreased function of the dorsal column and the spinothalamic tract and stimulus-evoked pain (mechanical and thermal hyperalgesia and allodynia) [10–11]. Therefore, the use of these methods may help to diagnose the pain. When used in clinical trials, these methods may also help identify specific patterns of responsiveness that may predict pain relief. Although QST may potentially be a useful diagnostic and outcome measure after SCI, we recognize that only limited validity and reliability data are available (see Felix and Widerström-Noga, p. 69 of this issue), and further standardization studies are needed in those with SCI [13]. With the use of QST, together with validated questionnaires evaluating the sensory pain descriptors, the pattern of pain, and psychosocial functioning, complete pain phenotypes may be described.

Evoked and Spontaneous Pain

Most of the mechanisms that have been identified in animal models of SCI [42] are based on studies of evoked pain or reflex behavior. However, in the SCI patient, spontaneous ongoing pain, rather than evoked pain, is usually the most debilitating symptom. Although evoked and spontaneous pain often coexist after SCI, these symptoms may also exist independently, which raises the question of whether the mechanisms of evoked pain are identical to those causing spontaneous pain. Patients with syringomyelia who underwent QST appeared to fall into two different groups: one group with spontaneous burning pain and thermal sensory loss, assumed to reflect severe deafferentation, and another group with spontaneous and evoked pain and less thermal deficits, thought to reflect a central neuronal hyperexcitability [51]. This differentiation is supported in another study where a greater pain-relieving effect of lamotrigine was observed in SCI patients with evoked pain in the area of maximal pain than in those with spontaneous pain only [52]. An alternative interpretation of these differences is that the neuronal hyperexcitability is an underlying mechanism in both groups of patients. However, in patients as total deafferentation, i.e., in complete injuries, such hyperexcitability cannot be perceived as evoked pain below the level of injury by the patient. Therefore, neuronal hyperexcitability may possibly be an underlying mechanism in all SCI pains, but may only present as evoked pain below the level of injury in patients with incomplete injuries. This latter explanation is supported by the presence of hypersensitivity at the border zone in patients with below-level neuropathic pain, even in cases of complete SCI [47], and by similar pain-relieving

effects of lidocaine in patients with and without evoked pain [53]. Such subgroup analyses may be important for future trials because they may increase understanding of the underlying mechanisms of specific pain phenotypes with different underlying etiologies.

At- and Below-Level Pain

Differences in onset [28] and anatomical localization of the spinal lesion (nerve root and/or spinal cord) indicate different underlying mechanisms between these two types of neuropathic pain. A few treatment trials also support this differentiation. For example, mirror visual feedback with virtual walking relieved at-level neuropathic pain in four paraplegic patients [54]. However, a later study showed that imagining right ankle plantar- and dorsiflexion resulted in increased neuropathic pain in SCI patients with a complete thoracic injury [55]. In the first study, all subjects had at-level neuropathic pain (peripheral neuropathic pain due to root lesions), except for one person who had a thoracic injury and below-level neuropathic pain (central pain). In the second study, all patients had below-level neuropathic pain. The differential effect between at-level and below-level neuropathic pain suggests that these pain types may differ in the underlying mechanistic basis. However, other differences in study design (e.g., mirror feedback vs imagined movement) and patient population (incomplete vs complete injuries) may also explain the difference. Although the first study suggests that visual illusion therapy may significantly reduce at-pain neuropathic pain in selected subgroups of SCI, these results need to be confirmed in other studies.

In a patient with at-level neuropathic SCI pain, QST revealed severe thermosensory deficits in the neuropathic pain area, yet application of capsaicin in the neuropathic pain area induced a burning pain sensation, a decrease in heat pain threshold, and an increase in dynamic mechanical allodynia induced by a cotton swab [56]. This finding indicates that, despite a severe thermosensory deficit, integrity of heat-sensitive afferents remained. In addition, the partial pain-relieving effect of topical lidocaine suggested some involvement of primary afferents in generating at-level neuropathic pain in this patient. In patients with below-level neuropathic pain, topical capsaicin applied above, at, and below the level of injury did not increase the below-level neuropathic pain, and capsaicin applied below the level of injury in a group of patients with predominantly complete SCI did not induce spontaneous or evoked pain [57]. This finding implies that

peripheral input from small afferent fibers plays no role in below-level neuropathic pain, although the use of different and higher doses of capsaicin and the use of topical lidocaine may show other results [57].

At this point, an important and reasonable classification is between at- and below-level neuropathic pain, where clear differences exist in anatomic lesion site, onset, and possibly treatment effect. Further studies need to evaluate whether the distinction between spontaneous versus evoked pain, between complete versus incomplete lesions, and between different pain descriptors have any treatment implications.

PSYCHOSOCIAL FACTORS AND PAIN

Evaluation

Persistent pain, regardless of type, depends not only on pathophysiological mechanisms but also on a variety of psychosocial factors that can modulate the pain experience [1]. Therefore, the design of treatment interventions that are tailored to an individual's specific pain problem after SCI should be based on a comprehensive evaluation of pain that includes relevant psychosocial factors (i.e., cognitive, emotional, and social factors). Many assessment methods are available for the measurement of these specific factors in heterogeneous pain populations [58]. However, these instruments either may not be appropriate for assessing pain after SCI or they need to be adapted to this particular population [13], because other aspects of the injury (i.e., the physical impairment; sensory abnormalities; and decreased bowel, bladder, and sexual function) may confound the reporting of pain and the specific impact that pain has on an individual with SCI [59]. The development and testing of methods that can reliably assess pain and psychosocial factors after SCI is important because they may be used in standardized assessment strategies needed for multicenter trials and SCI research collaboration [13–14].

Some of the cognitive, emotional, and social factors relevant to the pain experience can be grouped to classify individuals with the use of a statistical procedure called cluster analysis. Several distinct subgroups of persons who experience chronic pain have been identified [60], and these subgroups have been suggested to reflect adaptation patterns to chronic pain. However, few studies have examined these adaptational pain patterns after SCI [61–62]. One instrument that has been used to identify adaptational

patterns in various chronic pain populations is the West Haven-Yale Multidimensional Pain Inventory, also known simply as the MPI [63], which is based on a cognitive-behavioral perspective and is designed to assess pain and self-reported behavioral and psychosocial factors associated with chronic pain. The MPI has been adapted to the SCI population in the Multidimensional Pain Inventory (Spinal Cord Injury version) (MPI-SCI) [64]. The psychometric properties of the MPI-SCI were recently examined in a sample of persons with SCI and found to be adequate for most of the subscales [65].

Adaptational Subgroups in Persons with SCI-Related Pain

Three different adaptational patterns have been identified in people with SCI who experience persistent pain [61–62]. One of these subgroups was characterized by higher levels of pain severity, affective distress, life interference, and lower levels of life control, similar to the Dysfunctional cluster previously described by Turk and Rudy [60]. Another subgroup was characterized by lower levels of pain severity, affective distress and life interference and higher levels of life control and general activities, comparable to the Adaptive Coper cluster identified in the original study [60]. However, in contrast to previous studies using the MPI, no subgroup corresponding to the Interpersonally Distressed subgroup characterized by high levels of pain and low levels of social, instrumental, and emotional support was detected. Instead, an adaptational subgroup specific to SCI was identified [61]. This subgroup, labeled the Interpersonally Supported, consisted of individuals who had relatively low psychosocial impact despite experiencing moderately high pain severities. Characteristic for this subgroup were high levels of positive pain-specific support and general intimate-interpersonal social support. In this context, interpersonal positive support in response to pain, in combination with intimate-interpersonal support, appears to be associated with greater life satisfaction, perhaps by moderating pain-related disability and depressed mood.

Social Support

Greater levels of social support may encourage various healthy behaviors, such as improved adherence to treatment and more adaptive coping mechanisms. However, the relationship between pain-related interpersonal responses and pain severity and treatment outcome is complex [66]. For example, low levels of social support were found to be associated with persistent pain and

appeared to moderate the relationship between stress and affective distress in a study including persons with SCI [67]. However, solicitous spouse behaviors and responses have also been known to be associated with both increased pain severity and pain disability in heterogeneous pain populations [68–69] and with depression and pain interference after SCI [70]. Interestingly, negative responses from significant others are also related to more pain and disability [69,71]. Therefore, the role of pain-related social support after SCI is possibly somewhat different than in other populations. For example, because a person with SCI may need social support regarding many aspects of his or her injury, pain-specific positive support may possibly be only solicited or offered when pain levels are relatively high.

Cognitive Factors

The relationship between cognitive factors, such as catastrophizing thoughts (i.e., irrational thoughts that something is far worse than it actually is) and negative pain beliefs, and impact of pain after SCI was recently examined in a study by Raichle et al. [72]. They found that catastrophizing thoughts and negative pain beliefs were related to both increased pain interference and poorer mental health. Similarly, another study identified greater levels of internal locus of control (i.e., the belief that an individual's own actions determine various events, such as extent of pain relief), adaptive coping, and less catastrophizing thoughts as predictive of a lower intensity of SCI-related pain [4].

Pain beliefs, including the extent to which an individual believes that his or her pain can be internally controlled (i.e., controlled by him- or herself), may be influenced not only by the type of pain but also by various other medical and psychosocial issues. For example, after SCI, locus of control has been shown to be related to many important issues, such as long-term adjustment [73], coping [74], psychological distress [75], and physical disability [76]. In addition, Boschen et al. found that internal locus of control influenced not only quality of life but also productivity, satisfaction with performance of daily activities, and community integration [73]. Using the MPI-SCI, in which life control is evaluated specifically with reference to pain, both severity of spontaneous pain [62] and frequency of evoked pain [77] were related to decreased perceptions of life control. Importantly, the perception of life control can be reinforced, and a study showed that education regarding medical complications improved sense of

control after SCI [78]. This observation is consistent with the observation that education, as part of a multidisciplinary program, appears to reduce the severity of neuropathic pain after SCI [79]. Therefore, (1) determining to what extent cognitive factors may influence the pain experience in each individual patient and (2) designing treatment strategies that include reducing the influence of negative cognitions and enhancing the sense of control and adaptive coping [21] in combination with therapies that reduce pain intensity are important.

Emotional Factors

Affective distress, such as depressed mood, anxiety, and anger, is closely related to the experience of chronic pain in a variety of heterogeneous populations [80]. However, the causality in these relationships is a matter of debate [81–82]. After SCI, greater psychological distress and excessive fatigue has been reported by individuals who experience persistent pain [83]. Moreover, persistent pain after SCI significantly affects emotional functioning [5]. This finding is supported by the observation that individuals classified by the MPI-SCI as belonging to the Dysfunctional subgroup report significantly more affective distress than the Interpersonally Supported and the Adaptive Copers subgroups [62].

In summary, factors like coping, catastrophizing, internal control, and affective distress are clearly related to the perceived severity of pain [4]. Research also shows that individual differences in dealing with pain significantly influence perceived severity of pain and quality of life [4,62], as well as life satisfaction after SCI [65]. These findings emphasize the strong interrelationships between psychosocial factors and SCI-related pain, and the need to identify psychosocial targets for treatment. Thus, psychological interventions aimed at increasing sense of internal control and improving adaptive coping may reduce both catastrophizing and affective distress and should be an integral part of a tailored pain-management strategy after SCI [21].

CONCLUSIONS

A mechanisms-based approach to treating pain has many advantages and may help provide better outcomes for patients. However, at present at least three challenges appear to exist: (1) to improve our understanding of the biological mechanisms underlying neuropathic pain fol-

lowing SCI; (2) to develop valid and reliable assessment tools that can accurately link specific clinical signs and symptoms, such as sensory QST profiles and pain characteristics, to a particular pathophysiological mechanism; and (3) to develop a consistent SCI pain taxonomy that includes psychosocial profiles so that these are systematically addressed as part of a mechanisms-based approach to treatment. In summary, successful management of SCI-related pain will ultimately depend on the ability to identify the underlying mechanisms of pain on an individual basis and then to tailor the treatment to these mechanisms.

Discussion in this article makes it clear that pain is ultimately a subjective experience that is not perceived until the nociceptive information is processed and modulated in the brain. Therefore, the conscious appreciation of pain and its impact on daily life are integral parts of the pain evaluation [84]. Because methods that can noninvasively assess brain processes are widely available today, increasing our understanding of supraspinal processing and modulation of pain is possible [85]. In addition, imaging studies can provide a greater understanding of the interrelationships between pathophysiological and psychosocial factors associated with chronic pain. For example, a study by Baliki et al. showed that the presence of chronic pain appeared to alter the functional connectivity of cortical regions involved with rest [86]. Furthermore, Baliki et al. hypothesized that the early stage of this cortical reorganization was driven by peripheral and spinal-cord mechanisms, while the later changes were related to the psychosocial factors associated with persistent pain. Therefore, methods involving imaging may help identify both spinal and supraspinal mechanisms of pain in people with SCI, and therefore imaging is likely to be an important complement to future studies seeking to elucidate the major contributors of persistent pain after SCI.

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